Ka-BAND INTERFERENCE TO THE TDRS-H,I,J SYSTEM FROM THE FIXED SERVICE, MOBILE SERVICE, FIXED SATELLITE SERVICE, AND INTER-SATELLITE SERVICE

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1. INTRODUCTION

National Aeronautics and Space Agency (NASA), European Space Agency (ESA), and National Space Development Agency of Japan (NASDA) are currently developing Data Relay Satellite (DRS) systems, which have forward and return Inter-Satellite Links (ISLs) in the 22.55 - 23.55 and 25.25 - 27.5 GHz bands. These bands are allocated to the Mobile Services (MS), Fixed Services (FS), and Inter-Satellite Services (ISS) on a primary basis. The 27 - 27.5 GHz band is also allocated on a primary basis[1] to the Fixed Satellite Service (FSS) Earth-to-Space Links in regions 2 and 3[2]. The DRS ISLs can be susceptible to interference from the FS, MS, FSS, and other ISS links. In order to ensure that the DRS links will not be significantly degraded by interference, the NASA/Goddard Space Flight Center (GSFC) Communications Link Analysis Simulation Systems (CLASS) project has developed interference environment models and software tools to calculate interference statistics. This paper describes the Ka-band interference environment to the Tracking and Data Relay Satellite System (TDRSS) from the FS, MS, FSS, and ISS emissions. It also describes some simulation tools CLASS uses to assess interference situations, provides a sample simulation result for the Tracking and Data Relay Satellite (TDRS) H,I,J system, and compares the result to the International Telecommunications Union (ITU) sharing criteria.

Section 2 identifies the systems operating in the TDRSS forward (22.55 - 23.55 GHz) band. Section 3 identifies the systems operating in the TDRSS return (25.25 - 27.5 GHz) band. Section 4 discusses software tools used to assess interference and provides a sample result.

2. SYSTEMS OPERATING IN THE TDRS FORWARD ISL BAND: 22.55 GHz - 23.55 GHz

2.1 SPACE SYSTEMS

CLASS personnel performed a search of all satellite systems registered with the ITU in the 22.55 - 23.55 GHz band and identified pertinent system parameters required for interference analyses. The results shown in Table 1 show that most satellite systems registered in this band are operating Geosynchronous Earth Orbiting (GEO)-to-Low Earth Orbiting (LEO) and LEO-to-LEO Inter-satellite Links. Although not allocated for this use, DRTS, COMETS, and HIBLEO are also operating Space-to-Earth downlinks. The ITU advance publication for the DRTS system indicates that this downlink is only for use with a compatibility simulator and that the DRTS will not transmit when its emissions can cause interference to another system. This probably also holds true for COMETS as the receiving station is the same as for the DRTS.

Filings have been submitted for several GEO satellite systems that are not included in Table 1 as their advance publication were not released to date. These include the USASAT, which consists of 72 different satellites. Table 1 also does not include DRTS-113E, DRTS-160E, and DRTS-177E, which are the Japanese DRSs located at 113° E, 160° E, and 177° E longitude. Both of these systems may use the whole 22.55 - 23.55 GHz band.

CLASS personnel assessed interference from the HIBLEO-2 (Iridium) satellite system and found that it will not cause interference to TDRSS [1].

In accordance with Space Network Interoperability Panel (SNIP) Ka-band recommendations among the three data relay systems of NASA, ESA, and NASDA, these relay satellites may generate a reference signal in the direction of the user spacecraft to allow for user spacecraft antenna acquisition. The reference signal may be either an unmodulated carrier, transmitted with the same frequency and polarization as the forward ISL, or a wide-beam beacon transmitted on Left Hand Circular Polarization (LHCP) at one of the following frequencies: 23.530 GHz, 23.535 GHz, 23.540 GHz, or 23.545 GHz. The reference signal Effective Isotropic Radiated Power (EIRP) towards the user spacecraft is approximately +24 dBW. The TDRS H,I,J satellites will use the unmodulated carrier at the same frequency and polarization as the forward ISL signal rather than the beacon. COMETS will use a forward beacon at 23.3875 and 23.54 GHz.

1. The Radio Regulations also define systems that are allocated to the 22.55 - 23.55 GHz and 25.25 - 27.5 GHz bands on a secondary basis. However, these systems are not considered here since they can not cause interference to the TDRSS ISLs as the ISLs have a primary allocation in these bands.
2. The Radio Regulations define regions 1, 2 and 3.

Table 1. Satellite Systems Operating in the 22.55 GHz - 23.55 GHz Band.

Type of Link	Agency	Transmit Satellite System					Receiving Station	Frequency (GHz)		Polarization	Transmit Characteristics			Receive Characteristics		
		Tx Satellite	Start Date	Period of Validity (Years)	Orbit	Beam		Min	Max		Max Tx Power Spectral Density dBW/Hz	Max Antenna Gain (dBi)	Antenna Pattern	Max Antenna Gain	Antenna Pattern	System Noise Temperature (˚K)
GEO-to-LEO ISL	USA	TDRS	10/25/ 1997	20	GEO: 41˚ W, 46˚ W, 171˚ W, 174˚ W	UFR	LEO User spacecraft	22.55	23.55	RHCP/ LHCP	-69	57	-	46.1 (Typical, but can vary)	-	-
	ESA	Artemis	10/1/ 1996	15	GEO: 16.4˚ E, 21.5˚ E	KDR	Envisat-1	23.12	23.55	RHCP/ LHCP	-64.9	53.4	See ITU Filing	-	-	-
						KDG	Envisat-1	23.12	23.55	RHCP/ LHCP	-53	20	See ITU Filing	-	-	-
		EDRSS	4/1/ 1996	15 years	GEO: 44˚ W, 32˚ E, 47˚ E, 59˚ E		LEO User spacecraft (Alt < 1000 km)	23.12	23.55	RHCP/ LHCP	- (62 dBW EIRP)	-	-	46.1 (Typical, but can vary)	-	-
	Japan	COMETS	8/1/ 1997	10	GEO: 121˚ E	FKR	ADEOS	23.383	23.392	RHCP	-70.2	55.9	See ITU Filing	48.9	See ITU Filing	850˚
		DRTS	8/1/ 2000	15 years	GEO: 90˚ E, 170˚ W	FKR	ADEOS (alt: 797 km, incl: 98.6˚)	23.00	23.55	RHCP/ LHCP	-49.5	57.4	See ITU Filing	48.9	See ITU Filing	850˚
ISL	USA	HIBLEO-2 (66 satellites)	2/1/ 1996	-	alt: 780 km incl: 86.5˚	ISF, ISR	Other HIBLEO-2 satellites	23.193	23.368	V	-67.5	36.7	Rec 465-3	36.7	Rec 465-3 (D/λ = 24.3)	1188˚ with sun illum, 720˚ otherwise
		MSS-LEO-1	10/22/ 1999	15	alt: 1300 km, incl: 47˚ - 90˚	IIR	Other MSSLEO-1 satellites	22.55	23.55	-	-65.3	36.0	Rec 465	36.0	-	-
		MSS-LEO-2	1/1/ 1998	-	alt: 780 - 1300 km, incl: 47˚ - 90˚	36R	Other MSSLEO-2 satellites	22.55	23.55	-	-55.3	46.7	Rec 465	46.7	Rec 465-3	720˚

Table 1. Satellite Systems Operating in the 22.55 GHz - 23.55 GHz Band (Cont)

		Transmit Satellite System						Frequency (GHz)			Transmit Characteristics			Receive Characteristics		
Type of Link	Agen-cy	Tx Satellite	Start Date	Period of Valid-ity (Years)	Orbit	Beam	Receiving Station	Min	Max	Polariz-ation	Max Tx Power Spectral Density dBW/Hz	Max Antenna Gain (dBi)	Antenna Pattern	Max Antenna Gain	Antenna Pattern	System Noise Temper-ature (˚K)
Space-to-Earth[1]	USA	HIBLEO (Typically 24 sats, but the number can vary)	6/1/1995	-	alt: 1300 km, incl: 47˚ - 90˚	36R[1]	T2 and T3 Earth Stations	22.55	23.55	-	-65.3	36	-	-	CCIR Rec 465	1200˚
	Japan	COMETS	8/1/1997	10	GEO: 121˚ E	23R[1]	ICE-KSA-TYP/SIM	23.157	23.550	RHCP/LHCP	-56.4	55.9	-	-	Rec 580	335˚
						G23[1]	ICE-KSA-TYP/SIM	23.384	23.554	RHCP/LHCP	-47.1	21.6	-	-	Rec 580	335˚
		DRTS	8/1/2000	15	GEO: 90˚ E 170˚ W	23R[1]	ICE-KSA-TYP/SIM	23	23.55	RHCP/LHCP	-49.5	57.4	-	-	Rec 580	200˚
						G23[1]	ICE-KSA-TYP/SIM	23	23.55	RHCP/LHCP	-43.1	21.6	-	-	Rec 580	200˚

1. Not in Accordance with the ITU Radio Regulations

2.2 TERRESTRIAL FS SYSTEM

FS systems currently operate in the 22.55 - 23.55 GHz band. ITU-R F.758 [2] describes the transmission characteristics of these systems.

3. TDRS RETURN ISL BAND: 25.25 GHz - 27.5 GHz

3.1 SPACE SYSTEMS

CLASS personnel performed a search for all satellite systems registered with the ITU in the 25.25 - 27.55 GHz band and identified pertinent system parameters required for interference analyses. The results shown in Table 2 shows that most satellite systems registered in this band are operating LEO-to-GEO ISLs and FSS Earth-to-Space Uplinks in the 27 - 31 GHz band. Although not allocated for this in the 25.25 - 27 GHz band, DRTS is also operating a Earth-to-Space uplink in the 25.25 - 27.5 GHz band. However, the ITU advanced publication for the DRTS system indicates that this uplink is only for use with a compatibility simulator and that the DRTS will not transmit when its emissions can cause interference to another system.

Filings have also been submitted for several geosynchronous satellite systems that are not included in Table 2 as their advance publications were not released to date. This includes the DRTS-113E, DRTS-160E, DRTS-170E, which are the Japanese DRSs at 113° E, 160° E, and 170° E longitudes, respectively. The DRTS operates at 25.25 - 27.5 GHz. This also includes ASIASAT, which consists of five satellites at 122˚E, 116˚ E, 105.5˚ E, 77.5° E, and 100.5° E, and THAICOM, which consists of 5 satellites at 78.5° E, 101° E, 120° E, 137.5° E, and 142.5° E. Both of these systems will use the 27 - 31 GHz band.

3.2 TERRESTRIAL FS SYSTEMS

There are two types of FS systems in this band: Point-to-Point (P-P) systems and Point-to-Multipoint (P-MP) systems. The P-P systems are radio relays that transmit from one station to another. The P-MP systems transmit from one station to several outlying stations in a broadcast mode.

3.2.1 P-P FS SYSTEMS

ITU Joint Ad Hoc Working Party (JAHWP) 7B-9D has been studying the sharing situation between the FS P-P systems and the ISS at 25.25 - 27 GHz. Information that the JAHWP 7B-9D received indicates that the FS could deploy 100,000 FS P-P stations worldwide by the year 2000. Although the exact deployment is not known, it is reasonable to assume that these FS stations will be deployed in and around the major cities of the world. The transmission frequency distribution can be assumed to be uniformly distributed across the 25.25 GHz - 27 GHz band. The channel bandwidths range from 2.5 MHz to 112 MHz. Since each FS station will only transmit on one frequency at a time, not all 100,000 stations will operate co-channel at a time. The number of FS stations operating co-channel in a 500 MHz band can range from 8 to 625 [3}. The EIRP density levels of the FS stations satisfy the following distribution: 70% of the stations transmit an EIRP density of 24 dBW/MHz or less, 25% of the stations transmit an EIRP density between 24 dBW/MHz and 33 dBW/MHz, and 5% transmit an EIRP density greater than 33 dBW/MHz [4]. The worst case weighted average EIRP density based on this distribution is approximately 36 dBW/MHz [3]. These P-P systems will have an antenna gain of 40 dBi and an antenna pattern that conforms to ITU-R F.699-2. Simulations have shown that the aggregate interference from these systems is not expected to be a problem except in the case of FS mainbeam interference [3]. JAHWP 7B-9D is developing a recommendation to limit the emissions of FS stations in the 25.25 - 27.5 GHz band. A description of the work and direction being taken by the Joint Ad Hoc (JAH) may be found in [5].

3.2.1 P-MP FS SYSTEMS

There currently are plans to implement a P-MP system, the Local Multipoint Communications System (LMCS), within Canada. A Canadian document, [6], showed that sharing between the DRS and the LMCS was feasible (but with low margins) since the Canadian system operates at very low power levels. Several Local Multipoint Distribution Systems (LMDS) have requested the use of the 27 - 27.5 GHz band within the United States (US). These systems operate at much higher transmission power levels than the LMCS. NASA has shown in [7] - [8] that sharing between the DRS and these LMDS is not feasible. Consequently, LMDS systems will not be implemented in the 27.0 - 27.5 GHz band in the US. The introduction of similar LMDS systems in other countries would have a significant impact on the performance of the TDRSS. The ITU needs to prepare a recommendation on the technical and operational characteristics of the P-MP systems in order to ensure that the operations of the DRSs in the 25.25 - 27.5 GHz band are protected.

4. SOFTWARE TOOLS AND SAMPLE RESULTS

CLASS personnel developed a software tool, called Communications Analysis Graphical Environment (CAGE), that can be used to assess interference to any spaceborne or terrestrial system from another spaceborne or terrestrial system. The tool and a sample result that shows the interference to TDRS from the Iridium satellite system are described in detail in [1].

Additionally, CLASS personnel developed another tool to calculate interference statistics from terrestrial interference sources and the effects of scattering. This tool was used to assess the effects of FS P-P systems on

Table 2. Satellite Systems Operating in the 25.25 GHz - 27.5 GHz Band

			Receiving Satellite System					Frequency (GHz)			Transmit Characteristics			Receive Characteristics		
Type of Link	Agency	Transmit Station	Receive Satellite	Start Date	Period of Valid-ity (Years)	Long-itude in GEO	Beam	Min	Max	Polariz-ation	Max Power Spectral Density dBW/Hz	Max Antenna Gain (dBi)	Antenna Pattern	Max Antenna Gain	Antenna Pattern	System Noise Temper-ature (˚K)
LEO-to-GEO	USA	LEO User spacecraft	TDRS	1/7/1997	20	41˚ W, 46˚ W, 171˚ W, 174˚ W	URR	25.25	27.5	RHCP/LHCP	-64.1	46.1 (Typical, but can vary)	-	60.4	Appendix 29, Annex 3	2455
	ESA	Envisat-1	Artemis	10/1/1996	15	16.4˚ E, 21.5˚ E	KDR	25.25	27.5	RHCP/LHCP	-69	-	-	54.2	See ITU Filing	1305
		User spacecraft (Alt < 1000 km)	EDRSS	4/1/1996	15	44˚ W, 32˚ E, 47˚ E, 59˚ E	-	25.25	27.5	RHCP/LHCP	-	46.1 (Typical, but can vary)	-	-	-	-
	Japan	ADEOS[1] (alt: 797 km, incl: 98.6˚)	COMETS	8/1/1997	10	121˚ E	RKR	25.773	25.927	RHCP	-53.9	49.7	See ITU Filing	56.9	See ITU Filing	383
			DRTS	8/1/2000	15	90˚ E, 170˚ W	RKR	25.25	27.5	RHCP/LHCP	-54	49.7	See ITU Filing	58.8	See ITU Filing	245
Earth-to-Space Links	Japan	SBE-K-KASHMA, SBE-K-TYP/TRK	COMETS	8/1/1997	10	121˚ E	KUN, KUT	27.146	27.953	RHCP	-35	- (EIRP: 86.2 dBW)	Rec 580	52.2	-	957
		SBE-K-TYP/TRK,					QUN, QUT	27.146	27.953	RHCP	-36	- (EIRP: 79.2 dBW)	Rec 580	51.2	-	937
		ICE-KSA-TYP/SIM					25R[2]	25.25	26.804	RHCP/LHCP	-48.2	- (EIRP: 68.1 dBW)	Rec 580	56.9	-	613
		ICE-KSA-TYP/SIM	DRTS	8/1/2000	15	90˚ E, 170˚ W	25R[2]	25.25	27.5	RHCP/LHCP	-37	- (EIRP: 80.8 dBW)	Rec 580	58.8	See ITU Filing	475
		KOBE-Ka, IBARAK1-Ka	MTSAT-135, MTSAT-140, MTSAT-145	8/1/2000	20	135˚ E, 140˚ E, 145˚ E,	UC1	27	31	H	-46.6	-	Rec 465	37.1	-	1040
		Australia-Ka					UC2				-49.9	-	Rec 465	37.1	-	1040
		Hawaii-Ka					UC3				-49.9	-	Rec 465	36.0	-	1040

1. Only user currently registered. However, DRTS will support other users in the future.
2. Not in accordance with ITU radio regulations.

Table 2. Satellite Systems Operating in the 25.25 GHz - 27.5 GHz Band (Cont)

Type of Link	Agency	Transmit Station	Receiving Satellite System: Receive Satellite	Start Date	Period of Valid-ity (Years)	Long-itude in GEO	Beam	Frequency (GHz): Min	Max	Polariz-ation	Transmit Characteristics: Max Power Spectral Density dBW/Hz	Max Antenna Gain (dBi)	Antenna Pattern	Receive Characteristics: Max Antenna Gain	Antenna Pattern	System Noise Temper-ature (˚K)
Earth-to-Space Links	Japan	Typical-Ka	Superbird-A2-Ka, Superbird-B2-Ka	1/1/2000	20	158˚ E, 162˚ E	KAR	27	31	-	-30	-	See Note	45.0	-	1330
	UK	Typical Earth Station (In region 2 for 27 - 27.5 GHz)	Afrisat-1, Afrisat-2, Afrisat-3, Afrisat-4	12/1/1996	20	19˚ E, 32˚ E, 38˚ E, 64.5˚ E	U2R	27	31	-	-33	-	Appendix 29, Annex 3	45	-	2000
		Typical Earth Station (In region 2 for 27 - 27.5 GHz)	SAMSAT-1, SAMSAT-2, SAMSAT-3	12/1/1996	20	75˚ W, 82˚ W, 89˚ W,	U2R	27	31	-	-33	-	Appendix 29, Annex 3	45	-	2000
		Typical Earth Station	SKYSAT-A1, SKYSAT-A2, SKYSAT-A3, SKYSAT-B1, SKYSAT-B2, SKYSAT-B3, SKYSAT-B4	12/1/1995	20	118.3˚ E, 121.5˚ E, 124.7˚ E, 133.2˚ E, 136.4˚ E, 139.6˚ E, 142.8˚ E	U3R	27	31	-	-33	-	Appendix 29, Annex 3	45	-	2000
		Typical-2 Earth Station	SKYSAT-C1, SKYSAT-C2, SKYSAT-C3, SKYSAT-C4, SKYSAT-C5	12/1/1996	20	80˚ E, 90˚ E, 101.5˚ E 104.8˚ E, 169.2˚ E	U2R	27	31	-	-33	-	Appendix 29, Annex 3	45	-	2000

Note: The antenna pattern for the TYPICAL-Ka Earth Station transmissions to the Superbird-A2-Ka and Superbird-B2-Ka satellites is:

$Gain(\theta) < 29 - 25 \log(\theta)$ for $3^\circ < \theta < 20^\circ$

$Gain(\theta) < 32 - 25 \log(\theta)$ for $20^\circ < \theta < 48^\circ$

$Gain(\theta) < -10$ for $48^\circ < \theta < 180^\circ$

Table 2. Satellite Systems Operating in the 25.25 GHz - 27.5 GHz Band (Cont)

Type of Link	Agency	Transmit Station	Receiving Satellite System					Frequency (GHz)		Polariz-ation	Transmit Characteristics			Receive Characteristics		
			Receive Satellite	Start Date	Period of Valid-ity (Years)	Long-itude in GEO	Beam	Min	Max		Max Power Spectral Density dBW/Hz	Max Antenna Gain (dBi)	Antenna Pattern	Max Antenna Gain	Antenna Pattern	System Noise Temper-ature (˚K)
Earth-to-Space Links	Korea	Typical-2 Earth Station	GLOBALSAT	7/1/1999	20	177.5˚ E	KUR	27	31	-	-39	-	Rec 465	43.5	See ITU Filing	600
		TTC					KO	27	31	-	-20.1	-	Rec 465	0	-	1200
		Typical-1 Earth Station	INFOSAT-A, INFOSAT-B, INFOSAT-C	7/1/1999	-	103˚ E, 113˚ E,	KUR	27	31	-	-39	-	Rec 465	43.5	See ITU Filing	600
		TTC				116˚ E	KO	27	31	-	-20.1	-	Rec 465	0	-	1200
	India	TYPICAL-KA-2	INSAT-13W, INSAT-75.2W, INSAT-108W	12/1/1999	20	13˚ W, 75.2˚ W, 108˚ W	K1R	27	31	-	-40	-	Appendix 29, Annex 3	47.0	-	2200
		TYPICAL-KA	INSAT-KA-50, INSAT-KA-54, INSAT-KA-63, INSAT-KA-67, INSAT-KA-74 INSAT-KA-76, INSAT-KA-78, INSAT-KA-83, INSAT-KA-87, INSAT-KA-93.5, INSAT-KA-98, INSATKA-100	9/30/1997	20	50˚ E, 54˚ E, 63˚ E, 67˚ E, 74˚ E, 76˚ E, 78˚ E, 83˚ E, 87˚ E, 93.5˚ E 98˚ E, 100˚ E	KRR	27	31	-	-40	-	Rec 580	47.0	-	2200

the performance of the TDRSS. Figure 1 depicts a sample result and shows the probability of exceeding specific interference levels given that the FS station is pointed directly at the TDRS. [9] states that the DRS interference level received from any system should not exceed -148 dBW/MHz more than 0.1% of the time. Figure 1 shows that the interference criteria is exceeded in the event of FS mainbeam interference. [5] describes steps that can be taken to reduce interference from FS systems.

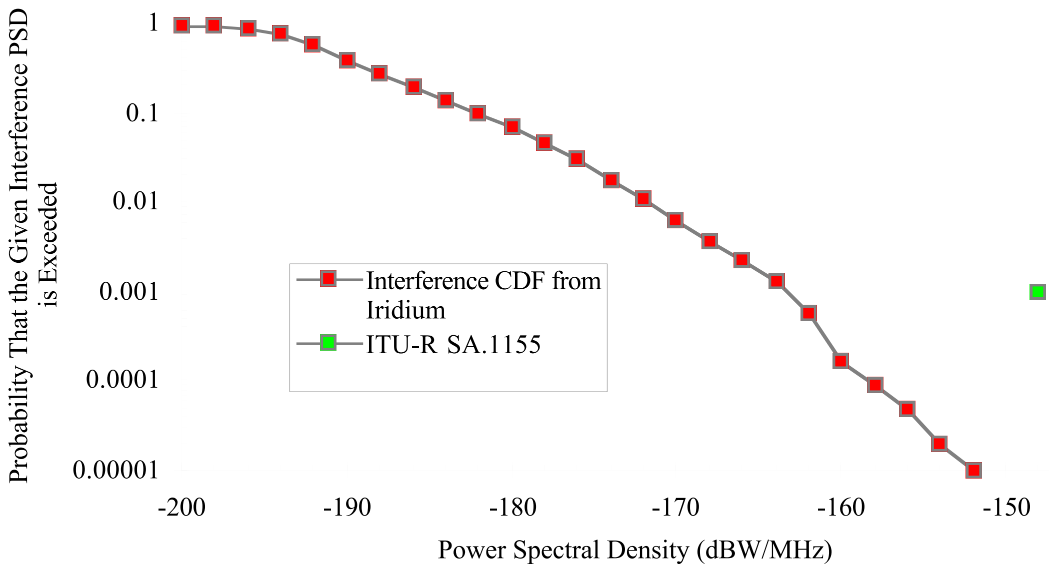

Figure 1. Interference Statistics for a TDRSS Return Service in the Event of Fixed Service Mainbeam Interference

5. REFERENCES

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